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The United States Looks to the Global Science, Technology, and Innovation Horizon

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U.S. STI (science, technology, and innovation) excellence and leadership are essential for national interests, e.g., economy, health, security, and environment. It is also important to U.S. diplomacy, its soft power, and efforts to advance peace, prosperity, and security around the world. Therefore, the U.S. STI enterprise will need to adapt to new opportunities and changes in the current landscape of global science. To be most effective, the response should include embracing a strategy of international STI research cooperation and utilizing STI knowledge strategically by looking *out, up, around, and forward*. This can empower the U.S. STI enterprise, especially its decentralized academic components, to engage globally.[1] We discuss a knowledge framework that could facilitate strategic international STI cooperation.

Embracing a National Strategy of International STI Research Cooperation

The overwhelming U.S. dominance in scientific research in the last half of the twentieth century is being replaced by a more multipolar landscape[2] of science, technology, and innovation, with the United States remaining a very strong force.

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The new data presented in the National Science Board's *Science and Engineering Indicators 2014* confirms what we already know—the United States is becoming less dominant in STI and there are substantial and increasing STI investments, linkages, and capacities now dispersed around the world. While the United States saw 4.9 percent growth from 2009 to 2011 in total research and development (R&D) expenditures, worldwide R&D spending increased over the same period by 15 percent. The U.S. share of worldwide R&D expenditures continued its decline; in 2000 it was 38 percent and in 2011 it stood at 30 percent.

These changes and others, for example in the global distribution of research excellence and STI infrastructure, have brought the United States to a challenge that can be converted into an opportunity.

Numerous U.S. national reports[3] have lamented the decreasing dominance of U.S. STI. A recommendation shared by these reports is to increase domestic STI spending, but national fiscal constraints are likely to limit such increases for the immediate future. Sustaining American STI leadership will need to involve vigorous STI international collaboration across the new dynamic landscape. If the United States can no longer be assured of leadership in STI through sheer dominance of size and resources, it will need to maintain *leadership through synergistic partnerships*. Such partnerships will yield mutual benefit for America and its partners by tapping great U.S. strengths, e.g., world-class scientists, students, and institutions and their immense creative capacity, entrepreneurial orientation, idealism, and generosity of spirit.[4]

Therefore international STI research cooperation, where it accelerates scientific progress and serves individual scientists, teams, and their institutions, should be embraced as a valuable national strategy, as advocated by the National Science Board in 2008.[5] Such a strategy will enable the nation to leverage scientific expertise, facilities, and funding around the world; continue to attract the "best and brightest"; train a globally engaged workforce; find new research and industrial partners and new markets; build strong international relationships; and drive innovative solutions for international development.

While national security concerns will necessarily restrict international collaboration on some topics, the Department of Defense has embraced an international science and technology strategy that includes unclassified basic research to strategically partner with allies to leverage their scientific portfolios and shared infrastructure, stay at the frontier of advanced scientific fields and technologies, train a globally engaged workforce, scan the horizon for emerging developments, and use science as a tool of diplomacy.[6]

As the global economy becomes increasingly interconnected, there is stronger competition for technological outputs of STI. Rather than viewing such interactions as a zero-sum game, U.S. scientists and institutions should sustain the free exchange of ideas and enter collaborations with strong agreements that articulate the mutual benefits for all participants and the arrangements for sharing outputs and benefits. U.S. companies are actively engaging and embracing new approaches

to open international collaboration. The International Technology Roadmap for Semiconductors—which for decades has teamed government, industry, and universities from around the world to direct the burgeoning information technology industry—is an example of a pre-competitive platform for cooperation that benefits all. Ideas embraced by the private sector (e.g., "open innovation" and "collaboration is the new competition") provide valuable lessons to the U.S. science enterprise as it seeks to find global "collaborative advantage."[7]

The United States takes seriously the responsibilities that come with STI leadership, and works to bring the power of its large STI enterprise to bear on cooperative global efforts to tackle the hardest problems that the world faces. STI can address global challenges and create sustainable and inclusive economic growth in countries at all stages of development.

The value of scientific knowledge dispersed across the world can increasingly be captured by those who build networks to take the local to global scale and bring the global back for local impact.[8] The opportunity lies in being able to develop the global STI knowledge infrastructure and tools to support global knowledge networks and partnerships.

The United States has the opportunity to exercise leadership in catalyzing the development of a more global STI knowledge commons. U.S. STI institutions will need to be at the center of rich global alliances and networks that can benefit the United States and its partners and can help address global challenges.

American Universities Looking Out, Up, Around, and Forward to the Global STI Horizon

Fostering increased strategic international collaboration in any nation requires rich information sources and tools; a diversity of models and mechanisms; a facilitative policy environment at national, state, and institutional levels; sufficient funding from international, national, state, private, and philanthropic sources; and an enabling legal and regulatory climate. A critical first step for the United States is to identify and address the knowledge needs of U.S. STI leaders—particularly universities given their strengths in education, research, service, and innovation—as they plan strategic international engagement. We use the phrase "looking to the horizon" to encapsulate the strategic gathering of such knowledge with needed resources and tools.

Looking Out: To reap the diplomatic, development assistance, scientific, and economic benefits of collaboration, the United States needs to *look out* at the rest of the world for mutually beneficial opportunities for collaboration. Many universities are striving to do just this, facilitating curiosity-driven international research by faculty members, providing students with well-mentored international research experiences, and investing in international partnerships to add value and strategic

focus at the university level. Leaders at U.S. universities are striving to define their institutions' "value proposition" in a more international context by considering strengths and potential beyond the local and U.S. domestic playing fields. There are many examples of international institution-level STI partnerships, including international branch campuses, dual degree programs, and research and education centers, involving one or more U.S. institutions and one or more foreign institutions within a country or region. U.S. universities are keenly interested in the strategies and strengths of foreign universities and in the STI opportunities of different countries.[9] Outside of collaborative opportunities in the European Union and in a few individual countries, we find that information on the STI policies of other countries is not well known in the United States, and there are few mechanisms to share it with the U.S. STI enterprise. Such insights could help U.S. institutions build strong, productive, and sustainable STI partnerships.

Multiple opportunities for international cooperation are close at hand. As the first U.S. stop for many foreign governments and institutions, the Department of State regularly receives requests for help in partnering with the U.S. STI community. Because the United States has more than four thousand degree-granting institutions of higher education, such matchmaking is a daunting task. Therefore, as the United States looks to engage internationally in STI, it is essential that potential partners be able to readily access information about the many American STI-relevant institutions and activities.

Looking Up: Global challenges increasingly include complex phenomena. These require that those in the United States STI enterprise *look up* from single fields and institutions and identify where to best enlist broader approaches that span disciplines. The United States and many other nations are building such cross-disciplinary connections, for example in nanotechnology[10] and "convergence science," where nanotechnology, biotechnology, information technology, and cognition intersect.[11] Sharing lessons learned from such efforts could facilitate building the strong and varied networks of expertise and new technologies required to address issues such as sustainable development, rapid urbanization, climate change, water security, and public health. International collaboration can accelerate progress in cross-disciplinary areas because, as global knowledge mapping has shown,[12] weak connections among a set of scientific domains in one country can be strong in another.

Universities are increasingly building capacity that is not so discipline- or institution-bound and strengthening their abilities to sustain long-term international STI partnerships by leveraging their legacy of teaching, research, and international collaboration in culture, language, and international relations. A 2010 National Research Council report, "S&T Strategies of Six Countries: Implications for the United States," emphasized the importance of culture in whether and how countries become knowledge-based and innovative societies.

Looking Around: The new global landscape of science is more distributed and networked—the United States needs to *look around* at such linkages. Many scientific advances are now propelled not just by individuals working within individual labs, but increasingly by overlapping, fluid, and largely self-organizing networks of scientists, engineers, technologists, and entrepreneurs. These networks frequently extend across and beyond research intensive institutions. Networks of scientists are already being supported, for example, by the National Science Foundation (NSF) Research Coordination Networks and through initiatives such as the Higher Education Solutions Network (HESN) undertaken by the U.S. Agency for International Development (USAID). HESN is building diverse, often international, teams to tackle significant development challenges, making more information on development projects available domestically and internationally, and tying together people and results for stronger impact.

Thousands of U.S. scientists are currently conducting excellent collaborative STI research projects overseas and generating tremendous goodwill toward the United States. We have discovered that many leaders of U.S. universities do not readily know where their faculty members conduct research overseas. Because most international networks of scientists are self-organizing, many U.S. universities lack effective means to capture and communicate information about such international research linkages. No national clearinghouse exists to showcase these assets for science engagement and diplomacy. Moreover, many U.S. universities do not immediately think of U.S. embassies and consulates as a resource and share their foreign activities with these potential linkage points. Some universities, however, are starting to build the capacity to map their international networks with a range of tools (e.g., the UCosmic Consortium—an international open-source software initiative).

Looking Forward: The rapid pace at which science expands across the global landscape suggests that the U.S. STI enterprise also needs to *look forward*, to work to shape the way STI advances and to understand and potentially mitigate adverse impacts. Many unclassified reports—ranging from U.S. NGO (nongovernmental organizations) and academic efforts (e.g., Science and Technology Outlook 2005-2055[13] and SciCast[14]) to assessments of the transformational potential and disruptive impacts posed by new technologies,[15] horizon-scanning business activities,[16] and various kinds of STI scenario-building and priority setting undertaken by regional and national entities[17]—are regularly produced to examine global scientific trends and look forward. Such studies can perform an essential national function by focusing on how global STI trends might influence U.S. strategy.

We find that many of these national and international reports are little known in the United States outside of Washington, DC. But a recent survey[18] suggests university leaders desire such information as they maneuver in the globally competitive academic arena to position their institutions close to science frontiers

that match their strengths. University leaders ask for our insights into global STI trends and we share what we know about forward-leaning activities undertaken by many countries.[19]

A Platform to Help Looking to the Horizon

Information on national and international science priorities, forward-looking activities, and knowledge mapping needs to be organized, synthesized, and made more widely available across the decentralized American STI enterprise. This includes information to identify trends in cross-disciplinary connections,[20] in innovators and agents of change,[21] or in geographic STI distributions and linkages.[22, 23, 24] So too does information on activities of U.S. academe, to put American institutions a few clicks away from potential partners, be they domestic or international. Such information would establish a solid base from which to nourish and grow global knowledge networks.[25]

There are already dozens of programs for research profiling and analytics being undertaken by business (e.g., Elsevier's SciVal, Thomson Reuters' InCites Research Analytics, Academic Analytics, and ResearchGate) and academic consortia[26] on behalf of STI-related institutions and state and federal governments. These frameworks are being developed for multiple purposes, e.g., to derive metrics for science policy, to evaluate the effectiveness of STI activities, and to find synergies via research collaboration, coordination, and leveraging. Now that STI is so global, knowledge platforms should also be designed to help facilitate broad, long-lasting international STI partnerships between institutions.

As more U.S. and foreign institutions invest in different data frameworks to visualize productivity and connectivity, there can be a cascade of increased participation and utility by stakeholders. We envision a socio-technical knowledge platform and associated visual interfaces that would describe many facets of global STI portfolios. A key function would be to accelerate matchmaking between institutions, thus benefitting U.S. institutions and their partners, many of whom have resources for supporting international STI projects. Having rich and robust databases and state-of-the-art knowledge mapping algorithms and tools that can elucidate science distributions and networks should inform strategic decision making at many levels.

Such a platform has the tremendous potential to catalyze discussion, convene stakeholders, and encourage implementation. The stakeholders include universities, university associations, companies, foundations, science organizations, and science funding entities. They would shape, implement, and own the envisioned knowledge platform.[27]

Essential Properties of a Platform

To function best at facilitating institutional partnerships, the important properties of such a knowledge platform should incorporate the following:

Wide Inclusion: The platform should make available information about the full range of U.S. institutions of higher education, starting with the largest. Also included should be information about a wide set of institutions in other countries, including countries with small academic footprints. It is essential that a global platform narrow, not widen, any digital divide between developed and less developed nations, so that partners and solutions can be found at any level.

Rich Content: The platform should build upon research analytics frameworks and also capture information about teaching, training, facilities, business partnerships, and existing international engagement across scientific and nonscientific disciplines. Because institutional partnerships are about people, we expect they will thrive when there are compatibilities across multiple dimensions.

Broad Access: The platform should be accessible to all who want to use it in the United States and abroad. Easy-to-use online interfaces as well as programmatic access to data will make it maximally useful.

Interoperable Structure: To weave together the many strands of relevant information, the platform should add value to and link many existing programs. The idea is not to create a monolithic structure, but to find common definitions, standards, and programs to interlink existing frameworks, for example in different countries, states, universities, and disciplines (e.g., Brazil's Lattes Platform, North Carolina's ReachNC, Duke University's Scholars@Duke, and the Neuroscience Gateway). The platform's structure should enable analysis across sectors and at national, institutional, and individual scales.

High Incentives and Low Barriers: The incentive for an institution's participation is to see and be seen in the vibrant knowledge networks and partnerships that increasingly span the globe. The platform requires highly visible "early adopters" to use it and demonstrate its value. Once enough institutions participate, the value to all would grow. Adoption of the platform should minimize for an institution both the cost and the time required for data entry (especially by science faculty). This is likely if the platform takes advantage of existing databases at universities and in the government (e.g., MEDLINE, U.S. Patent and Trademark Office Search for Patents, NSF Award Search, and the National Institutes of Health RePORT) and information extracted from them, national research networking data platforms that make university data accessible (e.g., VIVO Consortium, Harvard Profiles), programs that track an institution's international footprint (e.g., the UCosmic

Consortium and moveon[28]), and, if needed, data harvested from websites by appropriate "smart" tools such as search engines (e.g., Google Scholar and Citeseer) and pre-populated scholar profiling systems (e.g., Pivot). The platform should support easy addition of new and updated datasets and interfaces, and the plug-and-play of value-adding services such as search, data mining, analysis, and visualization tools.

Contextual Insights: In addition to data and tools, the platform would provide information on different models of collaboration, "lessons learned" and effective practices from different geographic areas, and information about science and technology priorities, strengths, facilities, and programs in countries and regions around the world.

Foresight Capacity: The platform would provide access to the products of forward-looking activities—such as technology assessments, roadmaps, foresight reports, and projections—to point to new opportunities on the horizon.

Going Forward

The number and diversity of U.S. universities and the strength of their faculty, students, alumni, facilities, and industry alliances are an integral part of the United States' national STI fabric and creative genius. When arrayed alongside the many foreign institutions and their strengths, there is a huge matrix of potential partnerships. A platform that elucidates this multidimensional matrix and provides information and tools to explore STI strengths and trends around the world would enable leaders of U.S. and foreign universities to more effectively find partners, respond to changes in the STI landscape, and nimbly engage in strategic international cooperation. Filling that matrix could also allow institutions to find their unique international "value proposition," reduce competition among institutions, and enrich the nation's international STI portfolio. This, in turn, would strengthen international relationships, enable the United States to sustain its STI excellence and leadership, and bring U.S. talents to bear on global challenges, thus advancing knowledge, peace, and prosperity around the world. The challenge is how to build such a platform and to create the consensus to make it happen. SD

Endnotes

1. "Looking to the STI Horizon" was the theme of a recent symposium that we organized at the AAAS (American Association for the Advancement of Science [publisher of *Science & Diplomacy*]) Annual Meeting in Chicago in February 2014, where our ideas benefited greatly from contributions of our panelists, discussants, and audience in that session.

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   Committee on Research Universities, Board on Higher Education and Workforce, Policy and Global Affairs, *Research Universities and the Future of America* (Washington, DC: The National Academies Press, 2012).
4. For example, as typified by widespread American support for the Peace Corps. See Jamie Price. 2012. "Practical Idealism: How Sargent Shriver Built the Peace Corps."
5. *International Science and Engineering Partnerships: A Priority for U.S. Foreign Policy and Our Nation's Innovation Enterprise* (Arlington, VA: National Science Board, February 14, 2008), http://www.nsf.gov/pubs/2008/nsb084/nsb084_1.pdf.
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13. The Institute for the Future, *Science and Technology Outlook 2005-2055*, 2006, http://www.iftf.org/our-work/people-technology/technology-horizons/science-technology-outlook-2005-2055.
14. SciCast is run by AAAS and George Mason University.
15. For example, the Department of Commerce's "Deep Dive in Space"; the Air Force's "Technology Horizons"; the National Intelligence Council's "Global Trends 2030: Alternative Worlds"; a 2012 report from The National Academies entitled "Rising to the Challenge," which specifically examined other countries' STI strategies; and USAID's 2013 report "The Future Can't Wait: Over-the-Horizon Views on Development."
16. For example, the International Technology Roadmap for Semiconductors, the World Technology Evaluation Center, McKinsey & Company's "Disruptive technologies," and IBM yearly roadmaps.
17. For example, Australia's "Foresight for Our Future"; the UK's online collection of science foresight projects, South Korea's International Foresight Symposium; and Germany's "Foresight Process."
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26. Katy Börner, Mike Conlon, Jon Corson-Rikert, and Ying Ding, eds., *VIVO: A Semantic Approach to Scholarly Networking and Discovery*. (San Rafael, CA: Morgan & Claypool Publishers LLC, 2012).
27. We use the term "platform" in a broad sense to include a wide range of IT programs, a clearinghouse of relevant information, search and visual analytics functionality, and other functions that the stakeholders might prioritize.
28. moveon is an internationalization and academic mobility software system, http://www.qs-unisolution.com/portfolio/moveon/about.html.

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